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(54)[Title of the Invention] IMAGING METHOD AND EXPOSURE APPARATUS USING THE METHOD AND DEVICE FABRICATING METHOD USING THE METHOD

(57)[Abstract]

[Object]

To provide an imaging method for projecting a pattern having a periodicity by a high resolution by using a light beam in an optimum polarized state and an exposure apparatus using the method.

[Constitution]

When a pattern having a periodicity on a reticle face is illuminated by a light beam from an illumination system and an image of the pattern is projected onto a wafer face by making diffracted light generated from the pattern incident on a pupil of a projection optical system, a light beam of linearly polarized light having a polarizing plane in a direction

substantially orthogonal to a direction in which a period of the pattern becomes the shortest is selected to project by a polarization apparatus.

[Claims]

[Claim 1]

An imaging method characterized in that a pattern in a line-like shape is imaged by a polarized beam polarized in a longitudinal direction of the pattern.

[Claim 2]

The imaging method according to Claim 1, characterized in that the pattern is illuminated by the polarized beam.

[Claim 3]

The imaging method according to Claim 1, characterized in that the pattern is illuminated by a beam which is not polarized, and the polarized beam is extracted from a beam from the pattern.

[Claim 4]

The imaging method according to Claim 1, 2 or 3, characterized in that imaging of the pattern is carried out substantially by two of diffracted beams from the pattern.

[Claim 5]

The imaging method according to Claim 4, characterized in that a beam for illumination is obliquely incident on the pattern.

[Claim 6]

The imaging method according to Claim 4, characterized in that the pattern includes a phase shifter.

[Claim 7]

A device fabricating method characterized in that a pattern in a line-like shape is focused on a work piece by a polarized beam polarized in a longitudinal direction of the line and a device is fabricated by transcribing the pattern on the work piece.

[Claim 8]

The device fabricating method according to Claim 7, characterized in that the pattern is illuminated by the polarized beam.

[Claim 9]

The device fabricating method according to Claim 7, characterized in that the pattern is illuminated by a nonpolarized beam, and the polarized beam is extracted from a beam from the pattern.

[Claim 10]

The device fabricating method according to Claim 7, characterized in that imaging of the pattern is carried out substantially by two of diffracted beams from the pattern.

[Claim 11]

The device fabricating method according to Claim 10, characterized in that a beam for illumination is obliquely incident on the pattern.

[Claim 12]

The device fabricating method according to Claim 10, characterized in that the pattern includes a phase shifter.

[Claim 13]

An exposure apparatus characterized in that a pattern in a line-like shape is illuminated by a polarized beam polarized in a longitudinal direction of the pattern by illuminating means, the pattern illuminated by the polarized beam from the illuminating means is projected onto a substrate by projecting means to be exposed thereby.

[Claim 14]

The exposure apparatus according to Claim 13, characterized in that the illuminating means makes the polarized beam obliquely incident on the pattern.

[Claim 15]

An exposure apparatus characterized in that a pattern in a line-like shape is illuminated by a nonpolarized beam by illuminating means, and the pattern illuminated by the nonpolarized beam from the illuminating means is projected onto a substrate by a polarized beam polarized in a longitudinal direction of the pattern by projecting means to be exposed thereby.

[Claim 16]

The exposure apparatus according to Claim 15, characterized in that the illuminating means makes the nonpolarized beam obliquely incident on the pattern.

[Claim 17]

An imaging method characterized in that a repeated

pattern is imaged by a polarized beam polarized in a direction substantially orthogonal to a direction in which a period of repetition is minimized.

[Claim 18]

The imaging method according to Claim 17, characterized in that the pattern is illuminated by the polarized beam.

[Claim 19]

The imaging method according to Claim 17, characterized in that the pattern is illuminated by a beam which is not polarized, and the polarized beam is extracted from a beam from the pattern.

[Claim 20]

The imaging method according to Claim 17, characterized in that the pattern includes a pattern comprising a line and a space.

[Claim 21]

The imaging method according to Claim 17, characterized in that the pattern includes a pattern in a dot-like shape.

[Claim 22]

The imaging method according to Claim 17, 18, 19, 20 or 21, characterized in that imaging of the pattern is carried out substantially by two of diffracted beams from the pattern.

[Claim 23]

The imaging method according to Claim 22, characterized in that a beam for illumination is obliquely incident on the

pattern.

[Claim 24]

The imaging method according to Claim 22, characterized in that the pattern includes a phase shifter.

[Claim 25]

A device fabricating method characterized in that a repeated pattern is imaged onto a work piece by a polarized beam polarized in a direction substantially orthogonal to a direction in which a period of the repetition is minimized, and a device is fabricated by transcribing the repeated pattern onto the work piece.

[Claim 26]

The device fabricating method according to Claim 25, characterized in that the pattern is illuminated by the polarized beam.

[Claim 27]

The device fabricating method according to Claim 25, characterized in that the pattern is illuminated by a nonpolarized beam, and the polarized beam is extracted from a beam from the pattern.

[Claim 28]

The device fabricating method according to Claim 25, characterized in that the pattern includes a pattern comprising a line and a space.

[Claim 29]

The device fabricating method according to Claim 25, characterized in that the pattern includes a pattern in a dot-like shape.

[Claim 30]

The device fabricating method according to Claim 25, 26, 27, 28 or 29, characterized in that imaging of the pattern is substantially carried out by two of diffracted beams from the pattern.

[Claim 31]

The device fabricating method according to Claim 30, characterized in that an illumination beam is obliquely incident on the pattern.

[Claim 32]

The device fabricating method according to Claim 30, characterized in that the pattern includes a phase shifter.

[Claim 33]

An exposure apparatus characterized in that a repeated pattern is illuminated by a polarized beam polarized in a direction substantially orthogonal to a direction in which a period of the repetition is minimized by illuminating means, and the pattern illuminated by the polarized beam from the illuminating means is projected onto a substrate by projecting means to be exposed thereby.

[Claim 34]

The exposure apparatus according to Claim 33,

characterized in that the illuminating means makes the polarized beam obliquely incident on the pattern.

[Claim 35]

An exposure apparatus characterized in that a repeated pattern is illuminated by a nonpolarized beam by illuminating means, and the pattern illuminated by the nonpolarized beam from the illuminating means is projected onto a substrate by a polarized beam polarized in a direction substantially orthogonal to a direction in which a period of repetition is minimized by projecting means to be exposed thereby.

[Claim 36]

The exposure apparatus according to Claim 35, characterized in that the illuminating means makes the nonpolarized beam obliquely incident on the pattern.

[Claim 37]

An image projecting method characterized in that a pattern having a periodicity is illuminated by a light beam of linearly polarized light in correspondence with a direction of a period of the pattern, and the pattern is projected onto a predetermined face by a projection optical system.

[Claim 38]

An image projecting method characterized in that a pattern having a periodicity is illuminated by a light beam of linearly polarized light having a polarized plane in a direction orthogonal to a direction of aligning the pattern,

and the pattern is projected onto a predetermined face by making diffracted light generated from the pattern incident on a pupil of a projection optical system.

[Claim 39]

An image projecting method characterized in that a pattern having a periodicity is illuminated by a light beam having a polarized plane in a direction substantially orthogonal to a direction in which a period thereof is minimized by way of a polarization apparatus capable of emitting a light beam from an illumination system by arbitrarily changing a polarizing direction of linearly polarized light, and the pattern is made to be projected on a predetermined face by making diffracted light generated from the pattern incident on a pupil of a projection optical system.

[Claim 40]

An exposure apparatus characterized in that when a pattern having a periodicity on a reticle face is illuminated by a light beam from an illumination system, diffracted light generated from the pattern is made to be incident on a pupil of a projection optical system, and an image of the pattern is projected onto a wafer face, the pattern is illuminated by a light beam of linearly polarized light having a polarized plane in a direction substantially orthogonal to a direction in which a period of the pattern is minimized.

[Claim 41]

An image projecting method characterized in that when a pattern having a periodicity is illuminated, and the pattern is projected onto a predetermined face by a projection optical system, the pattern is projected by using a light beam of linearly polarized light in correspondence with a direction of a period of the pattern.

[Claim 42]

An image projecting method characterized in that when a pattern having a periodicity is illuminated, and diffracted light generated from the pattern is made to be incident on a pupil of a projection optical system to project the pattern onto a predetermined face, the pattern is projected by using a light beam of linearly polarized light having a polarized plane in a direction orthogonal to a direction of aligning the pattern.

[Claim 43]

An image projecting method characterized in that when a pattern having a periodicity is illuminated by a light beam from an illumination system, and diffracted light generated from the pattern is made to be incident on a pupil of a projection optical system to project the pattern onto a predetermined face, the pattern is projected by selecting a light beam having a polarized plane in a direction substantially orthogonal to a direction in which a period of the pattern becomes the shortest by a polarization apparatus.

[Claim 44]

An exposure apparatus characterized in that when a pattern having a periodicity on a reticle face is illuminated by a light beam from an illumination system, and diffracted light generated from the pattern is made to be incident on a pupil of a projection optical system to project an image of the pattern onto a wafer face, a light beam of linearly polarized light having a polarized plane in a direction substantially orthogonal to a direction in which a period of the pattern becomes the shortest is selected and projected by a polarization apparatus.

[Claim 45]

A semiconductor element fabricating method characterized in comprising a step of preparing a negative having a circuit pattern and a wafer, and a step of exposing to transcribe the circuit pattern of the negative onto the wafer by the method according to any one of Claims 37, 38, 39, 41, 42, 43.

[Claim 46]

A semiconductor element characterized in being fabricated by the fabricating method according to Claim 45.

[Detailed Description of the Invention]

[0001]

[Industrial Field of Application]

The present invention relates to an imaging method and

an exposure apparatus using the method and a device fabricating method using the method.

[0002]

The invention particularly relates to an imaging method and an exposure apparatus using the method and a device fabricating method using the method useful when respective devices of IC or LSI, CCD, a liquid crystal panel, a magnetic head and the like are fabricated.

[0003]

Further, the invention relates to an image projecting method and an exposure apparatus using the same capable of illuminating an electronic circuit pattern (pattern) having a small line width on a recitle or mask (hereinafter, referred to as "reticle") face by a pertinent light beam to be projected onto a wafer face by a high resolution in a stepper constituting a fabricating apparatus of a semiconductor element.

[0004]

[Prior Art]

Since a request for highly integrated formation of a semiconductor chip of IC, LSI or the like is promoted, various improvements are carried out for promoting a resolution of a so-to-speak stepper (reduction projection exposure apparatus) for subjecting a circuit pattern illuminated by an ultra violet ray to reduction projection to transcribe.

[0005]

In a prior art, as a method of promoting a resolution, there have been adopted a method of increasing a numerical aperture (NA) of a reduction projection lens system, a method of shortening a wavelength of exposure light and the like. Further, recently, other than the methods, there is proposed a method particularly effective for imaging a small pattern having a periodicity (repeated small pattern) such as a phase shift method or an oblique incidence illuminating method and the like.

[0006]

Imaging of a small pattern having a periodicity will be explained as follows.

[0007]

Fig. 32 is a graph showing a repeated pattern comprising 3 pieces of small slits, the abscissa of the graph designates a pattern position X, the ordinate designates an amplitude transmittance T. In the diagram, light is transmitted through a portion having a transmittance of 1, light is blocked by a portion having a transmittance of 0.

[0008]

When the repeated pattern having such an amplitude transmittance is illuminated by coherent light, incident light is divided into diffracted light of 0th-order, +1st-order, -1st-order, and other higher orders. Among them, what contributes to forming an image is only diffracted light

incident on a pupil of a projection optical system, and generally, diffracted light of 0th-order, +1st-order, -1st-order is incident on the pupil of the projection optical system.

[0009]

Fig. 33 is an explanatory diagram showing amplitudes of diffracted light of 0th-order, ±1st-order on the pupil. In the diagram, numerals 100, 101, 102 designate respectively peak positions of diffracted light of 0th-order, +1st-order, -1st-order, and notation IA designates an amplitude.

[0010]

Fig. 34 shows an intensity distribution of a pattern image formed by diffracted light of 0th-order, ±1st-order. The ordinate designates an intensity I. In normal focusing, when a line width of the pattern becomes very small and only diffracted light of 0th-order is incident on the pupil of the projection optical system, the image of the pattern is no longer formed.

[0011]

In contrast thereto, according to a phase shift method, when light transmits through the repeated pattern, by devising the pattern such that phases of diffracted light from contiguous slits are shifted from each other by 180 degrees, a diffracted light component of 0th-order is prevented from appearing on the pupil of the projection optical system, and

the image of the pattern is formed by diffracted light of +1st-order and -1st-order.

[0012]

Fig. 35 shows an amplitude distribution produced on the pupil of the projection optical system when a repeated pattern comprising 3 pieces of small slits is projected by a phase shift method. In the drawing, numerals 103, 104 respectively designate peak positions of diffracted light components of +1st-order, -1st-order. In this case, when a period of repeating the pattern stays the same, a distance between peak positions 103, 104 becomes a half of a distance between peak positions of diffracted light of ±1st-order in Fig. 33. When the phase shift method is used, a spatial frequency of the pattern can apparently be reduced, and therefore, diffracted light of ±1st-order from a smaller pattern is incident on the pupil. Therefore, a resolution is promoted.

[0013]

Although the amplitude distribution on the pupil of Fig. 33 shows a case in which light is incident from a direction orthogonal to a plane on which the pattern is drawn, it is an oblique incidence method that the position of the amplitude distribution on the pupil is shifted in a transverse direction by making a light obliquely incident on the plane.

[0014]

Fig. 36 is an explanatory diagram showing an amplitude

distribution on a pupil when light is made to be obliquely incident on a repeated pattern such that diffracted light of 0th-order and +1st-order is incident on the pupil. In the diagram, numerals 105, 106 respectively designate peak positions of diffracted light of 0th-order, +1st-order.

[0015]

When it is conceived to form an image by two beams of diffracted light shown in Fig. 36, even in the oblique incidence method, similar to the case of the phase shift method, diffracted light from a smaller pattern can reach the pupil, and the resolution is promoted.

[0016]

[Problems that the Invention is to Solve]

It becomes apparent from a result of a simulation carried out by the inventor that an effect of promoting a resolution by the phase shift method or the oblique incidence illumination method is considerably related to a polarized state of light when a pattern having a periodicity is illuminated. Therefore, there poses a problem that unless a polarized state of illuminating light is brought into a state optimum for a pattern, a significant promotion of a resolution is not achieved even by using the phase shift method, the oblique incidence illuminating method or the like.

[0017]

It is an object of the invention to provide an imaging

method and an exposure apparatus using the method and a method of fabricating a device by using the method preferably improved for imaging a small pattern.

[0018]

Further, it is an object of the invention to provide an image projecting method preferable for fabricating a semiconductor element and an exposure apparatus using the same in which when a pattern having a periodicity is projected onto a predetermined face by a projection optical system, by pertinently setting a polarized state of a light beam used for projection in correspondence with a direction of a period of the pattern, the pattern can be projected by high contrast while maintaining a high resolution. Further, it is an object thereof to provide a method of fabricating a semiconductor element having a high integrated degree.

[0019]

[Means for Solving the Problem and Operation]

(1-1) A first mode of the invention is characterized in that in an imaging method of imaging a pattern in a line-like shape, the pattern is imaged by a polarized beam polarized in a longitudinal direction of the pattern.

[0020]

(1-2) A second mode of the invention is characterized in that in a device fabricating method of imaging a pattern in a line-like shape onto a work piece, and transcribing the pattern

onto the work piece, the pattern is imaged by a polarized beam polarized in a longitudinal direction of the pattern.

[0021]

(1-3) A third mode of the invention is characterized that in an exposure apparatus for exposing a substrate by a pattern in a line-like shape, the exposure apparatus comprising means for illuminating the pattern by a polarized beam polarized in a longitudinal direction of the pattern and means for projecting the pattern illuminated by the illuminating means onto the substrate.

[0022]

(1-4) A fourth mode of the invention is characterized in that in an exposure apparatus for exposing a substrate by a pattern in a line-like shape, the exposure apparatus comprising illuminating means for illuminating the pattern by a nonpolarized beam and projecting means for projecting the pattern illuminated by the illuminating means onto the substrate by a polarized beam polarized in a longitudinal direction of the pattern.

[0023]

(1-5) A fifth mode of the invention is characterized in an imaging method of imaging a repeated pattern, the pattern is imaged by a polarized beam polarized in a direction substantially orthogonal to a direction in which a period of repetition is minimized.

[0024]

(1-6) A sixth mode of the invention is characterized in that in a device fabricating method of imaging a repeated pattern onto a work piece, and transcribing the repeated pattern onto the work piece, the pattern is imaged by a polarized beam polarized in a direction substantially orthogonal to a direction in which a period of repetition is minimized.

[0025]

(1-7) A seventh mode of the invention is characterized in that in an exposure apparatus for exposing a substrate by a repeated pattern, the exposure apparatus comprising illuminating means for illuminating the pattern by a polarized beam polarized in a direction substantially orthogonal to a direction in which a period of repetition is minimized and projecting means for projecting the pattern illuminated by the illuminating means onto the substrate.

[0026]

(1-8) An eighth mode of the invention is characterized in that in an exposure apparatus for exposing a substrate by a repeated pattern, the exposure apparatus comprising illuminating means for illuminating the pattern by a nonpolarized beam and means for projecting the pattern illuminated by the illuminating means onto the substrate by a polarized beam polarized in a direction substantially orthogonal to a direction in which a period of repetition is minimized.

[0027]

(1-9) According to the invention, when a pattern is illuminated by a polarized beam, a polarizer plate (film) is formed on a substrate formed with the pattern, a light source of a laser or the like for generating the polarized beam is provided, or the polarizer plate (film) is provided in an optical system for the illumination.

[0028]

Further, according to the invention, when a pattern illuminated by a nonpolarized beam is imaged by a polarized beam, a polarizer plate (film) is formed on a substrate of a mask or the like formed with the pattern, or the polarizer plate (film) is provided in an optical system for the imaging.

[0029]

According to a preferable mode of the invention, a polarizer plate (film) is constituted to be able to rotate around an optical axis of a system such that an azimuth of the polarizer plate (film) of the illumination optical system or an imaging optical system can be changed. By the constitution, a polarized beam polarized in a desired direction can be formed.

[0030]

According to other preferable mode of the invention, a half-wave plate (film) is provided in the illumination optical system or the imaging optical system, and the half-wave plate (film) is constituted to be able to rotate around an optical

axis of the system to be able to change an azimuth of an optical axis of the half-wave plate (film). A polarized beam polarized in a desired direction can be formed by the constitution.

[0031]

Further, according to the invention, when patterns different from each other are formed on a substrate, longitudinal directions of the patterns differ from each other, or directions in which periods of repeating the patterns are minimized (minimum period direction) differ from each other, the respective patterns are imaged by polarized beams in correspondence with longitudinal directions or/and directions orthogonal to the minimum period directions of the respective patterns.

[0032]

When such an imaging is simultaneously carried out, nonpolarized beams are supplied in a state of providing polarizer plates (film) in correspondence with the respective patterns for the respective patterns, or in a state of providing a half-wave plate (film) for generating polarized light in correspondence with other pattern or patterns other than one pattern, a polarized beam in correspondence with the one pattern is supplied. The polarizer plate (film) or the half-wave plate (film) may be provided at least one of a light incidence side or a light emittance side of the pattern.

[0033]

When such an imaging is successively carried out, an illumination optical system or an imaging optical system is constituted as in the above-described preferable mode, and polarized beams in correspondence with the respective patterns are generated.

[0034]

According to a preferable mode of the invention, the pattern is illuminated by an illumination beam from an oblique direction, or a phase shifter is supplied to the pattern, and imaging is carried out substantially by two of diffracted beams from the pattern.

[0035]

(1-10) An imaging projection method of the invention is characterized in

(1-10-a) that a pattern having a periodicity is illuminated by a light beam of linearly polarized light in correspondence with a direction of a period of the pattern, the pattern is projected onto a predetermined face by a projection optical system.

[0036]

(1-10-b) characterized in that a pattern having a periodicity is illuminated by a light beam of linearly polarized light having a polarized plane in a direction orthogonal to a direction of aligning the pattern, diffracted light generated from the pattern is made to be incident on a pupil of a

projection optical system, the pattern is projected onto a predetermined face.

[0037]

(1-10-c) characterized in that a pattern having a periodicity is illuminated by a light beam having a polarized plane in a direction substantially orthogonal to a direction in which a period thereof becomes the shortest by way of a polarization apparatus capable of emitting a light beam from an illumination system by arbitrarily changing a polarizing direction of linearly polarized light, diffracted light generated from the pattern is made to be incident on a pupil of a projection optical system, the pattern is projected onto a predetermined face.

[0038]

(1-10-d) characterized in that when a pattern having a periodicity is illuminated, and the pattern is projected onto a predetermined face by a projection optical system, the pattern is projected by using a light beam of linearly polarized light in correspondence with a direction of a period of the pattern.

[0039]

(1-10-e) characterized in that when a pattern having a periodicity is illuminated, the pattern is projected onto a predetermined face by making diffracted light generated from the pattern incident on a pupil of a projection optical system, the pattern is projected by using a light beam of linearly

polarized light having a polarized plane in a direction orthogonal to a direction of aligning the pattern.

[0040]

(1-10-f) characterized in that when a pattern having a periodicity is illuminated by a light beam from an illumination system, and the pattern is projected onto a predetermined face by making diffracted light generated from the pattern onto a pupil of a projection optical system, the pattern is projected by selecting a light beam having a polarized plane in a direction substantially orthogonal to a direction in which a period of the pattern becomes the shortest by a polarization apparatus.

[0041]

(1-11) Further, an exposure apparatus of the invention is characterized in

(1-11-a) that when a pattern having a periodicity on a reticle face is illuminated by a light beam from an illumination system, and an image of the pattern is projected onto a wafer face by making diffracted light generated from the pattern incident on a pupil of a projection optical system, the pattern is illuminated by a light beam of linearly polarized light having a polarized plane in a direction substantially orthogonal to a direction in which a period of the pattern becomes the shortest.

[0042]

(1-11-b) that when a pattern having a periodicity on a reticle face is illuminated by a light beam from an illumination system, and an image of the pattern is projected onto a wafer face by making diffracted light generated from the pattern incident on a pupil of a projection optical system, the image is projected by selecting a light beam of linearly polarized light having a polarized plane in a direction substantially orthogonal to a direction in which a period of the pattern becomes the shortest by a polarization apparatus.

[0043]

[Embodiment]

First, before explaining respective embodiments of the invention, an explanation will be given of a so-to-speak scalar diffraction theory used in a simulation of a general imaging characteristic, and a theory used by the inventors for a simulation and more accurate than the scalar diffraction theory.

[0044]

According to the scalar diffraction theory, when a pattern of an object is illuminated, a Fourier transformation image of the pattern is formed on a pupil of a projection optical system, the Fourier transformation image is subjected again to Fourier transformation within a range of a numerical aperture (NA) of a projection optical system, and a pattern image of an amplitude distribution present on an image face

is formed. When this is expressed by an equation, an amplitude A (x, y) at a point (x, y) on the image face can be written as follows.

[0045]

[Equation 1]

$$A(x,y) = \iint F(U(x_1, y_1)) \exp\{ik(\alpha x + \beta y)\} d\alpha d\beta$$

In the equation, $F(U(x_1, y_1))$ is Fourier transformation of an amplitude transmittance $U(x_1, y_1)$ of the pattern, and the Fourier transformation is subjected again to Fourier transformation within a range of a pupil plane determined by the numerical aperture of the projection optical system. Incidentally, (α, β) in the equation designate coordinates on the pupil plane, and $F(U(x_1, y_1))$ becomes a function of (α, β).

[0046]

Although the equation is an equation when illuminating light is coherent, even when illuminating light is partially coherent, the equation stays basically the same although the equation becomes more or less complicated.

[0047]

Although in a simulation using the above-described equation, it becomes apparent by an investigation carried out by the inventors that although a correct result is provided when the numerical aperture of the projection optical system is small, a number of problems are posed when the numerical

aperture becomes large.

[0048]

A first problem of the above equation resides in that a polarized state of incident light is not take into consideration. This will be explained in reference to the drawings. The example of the repeated pattern comprising 3 pieces of slits will be used for the explanation.

[0049]

Fig. 26 draws the amplitude distribution on the pupil shown in Fig. 33 on a reference spherical face 111 constituting a reference by a Gaussian image point 110 of a projection optical system. When wave front aberration of the projection optical system is disregarded, an amplitude at point 110 on an image face 112 is determined by integrating an amplitude on the reference spherical face 111, further, an amplitude at a point shifted from the point 110 by a distance x on the image face 112 is determined from the distance x and coordinates on the reference spherical face 111, or calculated by integrating an amplitude on the reference spherical face 111 in consideration of a phase difference.

[0050]

From now on, to simplify the explanation, a discussion is limited to calculation of the amplitude at point 110. Further, the coordinate axes will be defined here.

[0051]

As shown by Fig. 26, an optical axis is defined as z axis, an axis orthogonal to z axis in paper face is defined as x axis and an axis in a direction orthogonal to paper face is defined as y axis. According to a way of thinking by the above-described scalar diffraction theory, the amplitude at point 110 is calculated in the form of adding an amplitude on the reference spherical face 111 as it is.

[0052]

There is polarization in light, for example, even beams of completely coherent light do not interfere with each other completely when polarizing directions thereof differ from each other, when the beams are, for example, orthogonal to each other, interference therebetween is not brought about at all.

[0053]

Assuming that a longitudinal direction of slits constituting a repeated pattern is in parallel with y axis, and the repeated pattern is provided with a period in an x axis direction, when the slits are illuminated by light from a direction in parallel with z axis, an amplitude distribution of Fig. 26 is formed on the reference spherical face 111. Assuming that illuminating light is constituted by linearly polarized light polarized in a y axis direction (direction in parallel with the slits), and a change in a polarized direction can be disregarded within the projection optical system, also polarizing directions at the respective points of the

amplitude distribution become the y axis direction at all of positions similar to the illumination light.

[0054]

Assuming that the amplitude distribution on the reference spherical face 111 is formed only by light of light diffracted by the slits which is polarized in the y axis direction, all of the polarizing direction of light reaching the image face 112 becomes the same. Also in this case, the amplitude at point 110 is calculated by integrating the amplitude on the reference spherical face 111 as it is.

[0055]

On the other hand, when illuminating light is linearly polarized light polarized in the x axis direction (direction orthogonal to the slits), as shown by Fig. 27, in a case of considering representative light rays 120 through 124 directed from the reference spherical face 111 to point 110, from a condition that a polarizing direction and a direction of advancing light are orthogonal to each other, polarizing directions of the light rays 120 through 124 respectively become as shown by arrow marks 125 through 129 of the drawing. Polarization in this case is provided with two x, z, polarization components, and it is necessary to consider the amplitude at point 110 for respective polarization components. An intensity of light at point 110 becomes a total of intensities provided from amplitudes by the respective

polarization components.

[0056]

Next, a result of carrying out a simulation by applying the way of thinking will be explained. First, in imaging using diffracted light components of 0th-order, +1st-order, -1st-order explained in reference to Fig. 33, final intensity distributions provided for two polarizing directions of illuminating light, that is, by which direction of the x axis direction and the y axis direction of polarization components is used in light diffracted from the slits respectively become as shown by Fig. 28, Fig. 29.

[0057]

Fig. 28 shows a case in which the polarizing direction of the illumination light is in parallel with the slits, and the image is formed only by the polarization component in the y axis direction. On the other hand, Fig. 29 shows a case in which the polarizing direction of the illumination light is orthogonal to the slits, and the image is formed as a total of the x polarization component and the z polarization component.

[0058]

There is shown imaging using two of diffracted light in three of diffracted light of 0th-order, +1st-order, -1st-order evaluated by a similar simulation as in a phase shift method or an oblique incidence illuminating method as follows.

[0059]

When only a result of an intensity distribution on the image face is shown, in a case in which the polarization direction of the illumination light is in the y axis direction (in parallel with the slits), an intensity distribution shown in Fig. 30 is constituted, in a case in which the polarizing direction is in the x axis direction (orthogonal to the slits), an intensity distribution shown in Fig. 31 is constituted.

[0060]

Here, a contrast of the image is considerably poorer in the case in which the polarizing direction is orthogonal to the slits than in the case in which the polarizing direction is in parallel with the slits owing to an influence of the polarization component in the z direction. In normal exposure, the illumination light is brought into a nonpolarized state, and therefore, the intensity distribution is constituted by averaging the intensity distributions of Fig. 30, Fig. 31, however, also in this case, the contrast is deteriorated in comparison with that of the intensity distribution of Fig. 31.

[0061]

In this way, it becomes apparent from the highly accurate simulation carried out by the inventors that the polarizing direction of the illumination light effects a significant influence on the imaging characteristic.

[0062]

Particularly, when the phase shift method, or the oblique incidence illuminating method is applied for promoting a resolution, by pertinently controlling the polarizing direction of the illumination light for a pattern having a periodicity to be projected, a resolution more than expected is achieved.

[0063]

The above-described is a result of the simulation with regard to the imaging characteristic carried out by the invention.

[0064]

Respective embodiments of the invention will be explained as follows.

[0065]

Fig. 1 is an outline view of an essential portion of embodiment 1 when an image projecting method of the invention is applied to a stepper (step and repeat type projection exposure apparatus) for fabricating a device of a semiconductor element or CCD or a liquid crystal panel or a magnetic head or the like.

[0066]

In the drawing, numeral 1 designates a light source of an ultra high pressure mercury lamp or the like. Light emitted from the light source 1 is made to be uniform in a light amount distribution thereof by an optical integrator 2, and

illuminates a pattern (circuit pattern) 4a on a face of a reticle 4 by an illumination lens 3 by way of an aperture 8 and a polarization apparatus 9. Light diffracted by the pattern 4a of the reticle 4 is made to be incident on a projection lens 5, and forms an image of the pattern 4a on a semiconductor wafer 6 mounted on a stage 7 by way of the projection lens 5.

[0067]

Here, according to light emitted from the optical integrator 2, all thereof does not reach the illumination lens 3, but only a portion thereof suitable for illumination is selected by the aperture 8 constituting an aperture stop placed to be proximate to the optical integrator 2, and when selected light transmits through the polarization apparatus 9, a polarized state is converted from a state of circularly or elliptically polarized light or nonpolarized light into linearly polarized light. The polarization apparatus 9 can change a polarizing direction of linearly polarized light in accordance with a condition of a direction of repeating the pattern 4a or the like.

[0068]

The reticle 4 is drawn with the circuit pattern 4a having a small line width for being transcribed onto the semiconductor wafer 6, and illuminating light incident on the reticle 4 by way of the illumination lens 3 transmits through the reticle

4 in accordance with the circuit pattern 4a. A photosentive material of a resist or the like is coated on the semiconductor wafer 6, where an image of the circuit pattern 4a can be transcribed.

[0069]

The projecting lens 5 projects the image of the circuit pattern 4a on the reticle 4 onto the semiconductor wafer 6 by reducing the image by a predetermined magnification (generally, 1/5 or 1/10). At that occasion, the reticle 4 and the semiconductor wafer 6 are adjusted to a predetermined positional relationship by driving the stage 7. When exposure to a certain shot on the semiconductor wafer 6 has been finished, the semiconductor wafer 6 is moved by a predetermined amount in a horizontal direction by the stage 7, where exposure of other shot on the semiconductor wafer 6 is repeated to carry out.

[0070]

According to the embodiment, as the circuit pattern 4a on the reticle 4, there is used a repeated pattern aligned with 5 pieces of slits extended in y direction shown in Fig. 2 in x direction and having a periodicity in x direction. In the drawing, numerals 10 through 14 designate openings, surroundings of the openings 10 through 4 are constituted by a light blocking portion, and light transmits through only the portions. Further, a dached anddotted line 15 is a reference

line drawn in a direction of repeating the openings 10 through 14 in the slit-like shape (x direction) and is used in later explanation.

[0071]

Here, a contrast of the image is promoted by illuminating the reticle 4 by a light beam in which a main light ray is inclined from a vertical direction relative to the reticle 4.

[0072]

Fig. 3 is a sectional view along the one-dotted chain line 15 of the pattern 4a of Fig. 2. As directions of inclining light beams 20, 21 by oblique incidence illumination method, as shown by Fig. 3, the main light ray of the light beam is made to be oblique in ZX plane repeating the pattern 4a. In order to satisfy the condition, according to the embodiment, the opening of the aperture 8 is constituted as shown by Fig. 4. Further, x axis is directed in a direction in which a period of repeating the pattern 4a is minimized.

[0073]

In Fig. 4, a hatched portion 22 is a light blocking region blocking light such that light does not pass therethrough. Two circular openings 23, 24 are light transmitting regions, and light from the regions 23, 24 contributes to imaging the pattern 4a. In the drawing, numeral 25 designates a reference line drawn to pass centers of the circular openings 23, 24.

[0074]

Illuminating light selected by the aperture 8 of Fig. 1 is made to be incident on the polarization apparatus 9. As shown by Fig. 5, the polarization apparatus 9 is constituted by a structure of transmitting only polarized light in y direction shown by an arrow mark 26 in the drawing in a polarized light component of light incident from an upper face of the polarization apparatus 9 and blocking polarized light in other direction. A dashed and dotted line 27 in the drawing is a reference line drawn in a direction orthogonal to the arrow mark 26. Arrangement of the reticle 4, the aperture 8, and the polarization apparatus 9 of Fig. 1 in horizontal planes is set such that the reference lines 15, 25, 27 respectively shown in Figs.2, 4, 5 are in parallel with each other.

[0075]

By the above-described constitution, by imaging and baking the pattern 4a such that the polarizing direction of the oblique incidence illuminating light is constituted by y direction in parallel with the slit direction of the pattern 4a, that is, the polarizing direction is made to be orthogonal to x direction in which the period of repeating the pattern 4a is minimized, as explained in reference to Fig. 30, the image having the high resolution and the high contrast is provided on the semiconductor wafer 6. A similar effect is achieved also in a case of a repeated pattern on a dot as the pattern on the reticle 4.

[0076]

Next, in the embodiment, an explanation will be given of a case in which the pattern 4a on the reticle 4 is not only constituted by a single pattern having a periodicity in one direction as shown by Fig. 2, but the pattern 4a is provided with two patterns respectively having periodicities in two vertical and horizontal directions (y, x) as shown by Fig. 6.

[0077]

In this case, a repeated pattern of a portion surrounded by a broken line 30 of Fig. 6 can excellently be projected and transcribed by using the above-described method. However, with regard to a repeated pattern of a portion surrounded by a broken line 31, a polarizing direction of illuminating light is in a direction orthogonal to the slit, and therefore, a similar effect is not achieved.

[0078]

Hence, according to the embodiment, the reticle of Fig. 6 is split into two sheets of reticles shown in Fig. 7 and Fig. 8 to be exposed separately. That is, with regard to the pattern of Fig. 7, as described above, baking is carried out by linearly polarized light polarized in y direction, with regard to the pattern of Fig. 8, baking is carried out after rotating the aperture 8 and the polarization apparatus 9 by 90 degrees centering on an optical axis in a horizontal face to be fixed by a driving apparatus, not illustrated, such that

illuminating light is obliquely incident on the reticle in a plane of repeating the pattern, and the polarizing direction of the illumination light is in a direction in parallel with a longitudinal direction of the slit, that is, the illumination light becomes linearly polarized light polarized in x direction. The method is not limited to the case in which the pattern of the slit is in the two vertical and horizontal directions but is similarly applicable also to a case in which the pattern is in other direction.

[0079]

Further, when two kinds of repeated patterns are present in one reticle as shown by Fig. 6, respective patterns are successively illuminated by using a masking blade provided at a location conjugate with the reticle, and the respective patterns are illuminated by polarized light by the above-described method.

[0080]

Although according to the embodiment, an explanation has been given such that the pattern on the reticle is formed by 5 pieces of lines and spaces, the embodiment is similarly applicable also to a line and a space pattern of other than 5 pieces. Further, a ratio of widths of the line and the space is not limited to 1 to 1 but the invention is similarly applicable also to a case in which a period of a pattern becomes irregular to some degree.

[0081]

Further, according to the embodiment, the polarization apparatus 9 may be arranged between the illumination lens 3 and the reticle 4 or between the reticle 4 and the projecting lens 5 or at inside of the projection lens 5 (on pupil plane).

[0082]

When the projection apparatus 9 is arranged between the reticle 4 and the projection lens 5, in diffracted light diffracted by the pattern 4a in accordance with the shape of the pattern on the reticle 4 by the polarization apparatus 9, polarized light polarized in a specific direction is selected, and only the selected polarized light beam is made to be incident on the projection lens 5. Further, the image of the pattern 4a is projected onto the wafer 6 by the polarized light beam.

[0083]

Next, embodiment 2 of the invention will be explained. An apparatus constitution of embodiment 2 is substantially the same as that of embodiment 1 of Fig. 1. A point of embodiment 2 which differs from embodiment 1 resides in that the phase shift method is applied to the pattern on the reticle 4.

[0084]

Fig. 9 is an explanatory view of the pattern 4a on the reticle 4 of the embodiment. Although as shown by the drawing, the pattern 4a is constituted by 5 pieces of openings 40 through

44 in a slit-like shape extended in y direction similar to embodiment 1 of Fig. 1, the pattern of Fig. 9 is characterized in providing a phase shifter for changing a phase of light transmitting through hatched portions 40, 42, 44 by 180 degrees relative to light transmitting through portions 41, 43.

[0085]

Further, according to the embodiment, there is used a shape of the aperture 8 by which only light from an opening of a circular portion 46 at a center surrounded by a light blocking portion of a hatched portion 45 can be transmitted as shown by Fig. 10.

[0086]

According to the embodiment, the pattern 4a and the aperture 8 are combined with the polarization apparatus 9 similar to that of embodiment 1, and a polarizing direction of illuminating light becomes a direction in parallel with a longitudinal direction of the slit (y direction) relative to the pattern 4a in Fig. 9. Thereby, an excellent pattern is baked by using the phase shift method.

[0087]

Further, even in a case in which the pattern 4a on the reticle 4 is not constituted by one kind as shown by Fig. 9 but a plurality of kinds repeated in directions different from each other as in Fig. 6, the case can be dealt with by carrying out baking by using a plurality of sheets of reticles for

respective patterns in the same direction or splitting the reticle by using a masking blade similar to embodiment 1.

[0088]

Next, embodiment 3 of the invention will be explained. Also an apparatus constitution of embodiment 3 is substantially the same as that of embodiment 1 of Fig. 1.

[0089]

According to the embodiment, the pattern 4a on the reticle 4 shown in Fig. 11 is used. In Fig. 11, numeral 4 designates the reticle, and a coordinates system thereof is determined such that an xy face is in parallel with the reticle 4 and z axis is orthogonal to the reticle 4 similar to the above-described respective embodiments. In Fig. 11, numerals 210 through 214 designate slit-like opening portions of pattern A, the opening portions 210 through 214 constitute a repeated pattern in x direction shown by an arrow mark 215.

[0090]

Similarly, numerals 220 through 224 designates slit-like opening portions of pattern B, opening portions 220 through 224 constitute a repeated pattern in y direction shown by an arrow mark 225. The phase shift method is applied to respective of pattern A, pattern B. Details of patterns A, B applied with the phase shift method will be explained in reference to Fig. 12.

[0091]

Fig. 12 draws a section along the arrow mark 215 with regard to pattern A shown in Fig. 11. In Fig. 12, numeral 230 designates a transparent glass substrate, a hatched portion 231 is a light blocking portion comprising chromium. The period pattern A is formed by the light blocking portion 231 and the opening portions 210 through 214. The phase shift method promotes a resolution of an imaging system by changing phases of light transmitting through the opening portions by 180 degrees each between the contiguous opening portions, and numerals 32 through 34 in Fig. 12 designate phase shifters for changing phases of light transmitting therethrough by 180 degrees.

[0092]

Also with regard to the period pattern B, a sectional view along the arrow mark 225 becomes similar to Fig. 12. In imaging the pattern by applying the phase shift method, illumination may be carried out from a direction orthogonal to the reticle 4 (z direction), and therefore, as shown by Fig. 13, there is used the aperture 8 in which a hatched portion 240 at a periphery constitutes an opening portion and a center 241 constitutes an opening.

[0093]

The embodiment is applied with the polarization apparatus 9 shown in Fig. 14. The polarization apparatus 9 is constituted to transmit only polarized light in y direction

indicated by a double arrow mark 50 in Fig. 14 in light incident thereon. That is, illuminating light of a stepper according to the embodiment becomes linearly polarized light having a polarized plane in the y axis direction after transmitting through the polarization apparatus 9.

[0094]

When the pattern 4a on the reticle 4 is illuminated by the above-described constitution, a relationship between patterns A, B and a polarizing direction of illuminating light becomes as shown by Fig. 15 and Fig. 16. That is, with regard to pattern A, as shown by Fig. 15, a polarizing direction 60 becomes in parallel with a longitudinal direction of a slit constituting the pattern, and this satisfies a condition of promoting a resolution as described above.

[0095]

On the other hand, with regard to pattern B, as shown by Fig. 16, a polarizing direction 61 becomes orthogonal to a longitudinal direction of the slit constituting the pattern, the resolution cannot be improved in pattern B as in pattern A when the constitution is as it is.

[0096]

Hence, according to the embodiment, by rotating a polarizing plane of a linearly polarized light beam incident on the pattern B by 90°, the pattern B is made to be illuminated by the linearly polarized light beam in a direction in parallel

with the slit of the pattern B.

[0097]

Fig. 17 is a plane view of the reticle 4 showing pattern A, pattern B similar to Fig. 11, however, the reticle 4 of Fig. 17 is characterized in that a polarization converting apparatus 70 for rotating a polarized plane of a linearly polarized light beam incident on immediately frontward from pattern B by 90° is polarized. As the polarization converting apparatus 70, for example, a half-wave plate is applicable. A behavior of rotating the polarized plane when the half-wave plate is applied will be explained in reference to Fig. 24.

[0098]

In Fig. 18, when a direction of an optical axis 82 of a polarization converting apparatus (here, a half-wave plate) is arranged to constitute an angle of 45 degrees relative to x axis for a linearly polarized light beam advancing in a direction of an arrow mark 80 and polarized in a direction of a double arrow mark 81 (y direction), a light beam after transmitting through the polarization converting apparatus 70 advances in a direction of an arrow mark 83 and is converted into a linearly polarized light beam polarized in the x axis direction as shown by a double arrow mark 84.

[0099]

By arranging the polarization converting apparatus 70 immediately before pattern B, a relationship between pattern

B and a polarizing direction of an illumination light beam becomes as shown by Fig. 19. That is, a direction of polarization indicated by a double arrow mark 90 is brought into a relationship of being in parallel with the slit constituting pattern B, and therefore, promotion of the resolution similar to that of pattern A can be realized also for pattern B.

[0100]

When an optical substance having an optical rotary power is applied as the polarization converting apparatus 70, a magnitude of rotating a polarized plane of a linearly polarized light beam can be controlled by a thickness of the polarization converting apparatus 70, in that case, an angle of rotating the polarized plane of the linearly polarized light beam can be set to a value other than 90 degrees by controlling the thickness, and therefore, the resolution can be promoted for repeated patterns in various directions.

[0101]

Although according to the embodiment, an explanation has been given such that the phase shift method is applied to the pattern to be illuminated, even when the oblique incidence illuminating method is used, the method is naturally applicable.

[0102]

There is a modified example of forming the polarization

apparatus 9 on a surface or a rear face of the reticle 1 in the above-described respective embodiments.

[0103]

Fig. 20 is an outline view of an essential portion of embodiment 4 when the image projecting method of the invention is applied to a stepper for fabricating a semiconductor element. Elements the same as elements shown in Fig. 1 are attached with the same notations.

[0104]

In Fig. 20, the light source 1, the optical integrator 2, the illumination lens 3, the reticle 4, the projection lens 5, the semiconductor wafer 6, the stage 7 and the like are respectively similar to those of Fig. 1, and therefore, an explanation thereof will be omitted here.

[0105]

A point of embodiment 4 which differs from embodiments 1 through 3 resides in a position in an optical path installed with a polarization apparatus. The embodiment is constructed by a constitution of arranging a polarization apparatus 59 immediately before a reticle 54 (between the illuminating lens 3 and the reticle 54) and controlling a polarized state of light incident on the reticle 54 immediately before the reticle 54.

[0106]

Here, a pattern 54a on the reticle 54 according to the embodiment is constituted by a repeated pattern constituted

by slits 60 through 64 extended in a vertical direction (y direction) and a repeated pattern constituted by slits 65 through 69 extended in a horizontal direction (x direction) as shown by Fig. 21. In order to promote a resolution for the patterns in the vertical and the horizontal directions by oblique incidence illumination, the opening of the aperture 8 may be constituted as shown by Fig. 22.

[0107]

In a hatched portion 70 in Fig. 22, circular opening portions 71 through 74 provided at four corners of a light blocking portion constitute light transmitting portions, and light from the openings 71 through 74 is made to be obliquely incident on the reticle 4.

[0108]

According to the embodiment, the polarization apparatus 59 is arranged such that a polarizing direction of light incident on the pattern 54a becomes always in parallel with a longitudinal direction of the slit for an oblique incidence illuminating method.

[0109]

Notations 59a, 59b in Fig. 21 designate polarizing members for transmitting only linearly polarized light polarized in a certain one direction in incident light, the polarizing member 59a is installed to transmit only polarized light polarized in a direction in parallel with a longitudinal

direction of the slits 60 through 64 (y direction) in incident light.

[0110]

On the other hand, the polarizing member 59b is arranged to transmit only polarized light polarized in a direction in parallel with a longitudinal direction of the slits 65 through 69 (x direction). As the polarization apparatus 59, an apparatus in which a polarizer in a shape of a thin film is pasted on the reticle 54 by determining a polarizing axis direction in accordance with the pattern in correspondence therewith or the like is applicable.

[0111]

Although according to the embodiment, the pattern 54a on the reticle 54 having the slits extended in two vertical and horizontal directions has been explained, the embodiment is similar applicable to a pattern having a slit extended in the other direction.

[0112]

Further, according to the embodiment, the polarization apparatus 9 may be arranged immediately after the reticle 54 (between the reticle 54 and the projection lens 55).

[0113]

At this occasion, the polarization apparatus 9 is made to be able to select polarized light polarized in longitudinal directions of slits independently respectively for slits in

respective directions in light diffracted from the slits even when there are slits extended in various directions on the reticle 54, further, imaging is carried out by the polarized light.

[0114]

Next, embodiment 5 of the embodiment will be explained. An apparatus constitution of embodiment 5 is substantially the same as that of embodiment 1 of Fig. 1. Embodiment 5 differs from embodiment 4 in that the phase shift method is applied to a pattern on the reticle 4.

[0115]

Fig. 23 is an explanatory view of a pattern 54a on a face of a reticle 54 according to the embodiment. Although the pattern on the reticle 54 shown in the drawing is constituted by slits 80 through 84 extended in the vertical direction (y direction), and slits 85 through 89 extended in the horizontal direction (x direction) similar to the pattern of Fig. 21, the embodiment differs therefrom in providing a phase shift member for changing a phase of light transmitting through hatched portions 80, 82, 84, 85, 87, 89 among the slits in the drawing relative to light transmitting through portions 81, 83, 86, 88 by 180 degrees.

[0116]

Notations 59a, 59b designate polarizing members, and when circularly or elliptically polarized light or

nonpolarized light is made to be incident on the reticle 54, only polarized light of the light polarized in a longitudinal direction of the slit is made to be incident thereon. Further, there is used the aperture 8 shown in Fig. 13 similar to the case of embodiment 2.

[0117]

According to the embodiment, by the above-described constitution, promotion of the resolution is achieved by the phase shift method, and even when there are patterns in vertical and horizontal directions on the reticle 54, the patterns are imaged on the semiconductor wafer 6 by polarized light suitable for the respective patterns.

[0118]

Although here, an explanation has been given of the pattern on the reticle 54 having the slits extended in two vertical and horizontal directions, the embodiment is applicable to a pattern having a slit extended in the other direction.

[0119]

Although here, there is shown a case of forming the patterns on the reticle by 5 pieces of lines and spaces as an example, the embodiment is similarly applicable to line and space patterns of other than 5 pieces. Further, a ratio of widths of a line and a space is not limited to 1 to 1 but the embodiment is applicable similarly also to a case in which a

periodicity of a pattern becomes irregular to some degree.

[0120]

Further, a laser emitting linearly polarized light may be made to constitute a light source for exposure without using a lamp and a polarization apparatus. Further, when a polarized apparatus is used or when a laser is used, a half-wave plate may be put into an optical path, and desired polarized light may be produced by rotating the half-wave plate.

[0121]

Next, an embodiment of a device fabricating method utilizing the exposure apparatus explained above will be explained. Fig. 24 shows a flow of fabricating a semiconductor element (a semiconductor chip of IC, LSI or the like, or a liquid crystal panel or CCD or the like).

[0122]

At step 1 (circuit design), a circuit of a semiconductor element is designed. At step 2 (mask fabrication), a mask formed with a designed circuit pattern is fabricated.

[0123]

On the other hand, at step 3 (wafer fabrication), a wafer is fabricated by using a material of silicon or the like. Step 4 (wafer process) is referred to as prestep, and a circuit of the embodiment is formed on the wafer by a lithography technology by using the prepared mask and wafer.

[0124]

Next, step 5 (integration) is referred to as poststep, and is a step of forming a semiconductor chip by using the wafer formed by step 4, and includes steps of assembly step (dicing, bonding), packaging step (chip seal in) and the like. At step 6 (inspection), there is carried out an inspection of operation confirm test, durability test or the like of the semiconductor element fabricated by step 5. After having been processed by the steps, the semiconductor element is finished and the semiconductor element is delivered (step 7).

[0125]

Fig. 25 shows a detailed flow of the wafer process.

[0126]

At step 11 (oxidation), a surface of the wafer is oxidized. At step 12 (CVD), an insulating film is formed on the surface of the wafer. At step 13 (electrode formation), an electrode is formed on the wafer by vapor deposition. At step 14 (ion implantation), ions are implanted to the wafer. At step 15 (resist process), the wafer is coated with photosensitive reagent. At step 16 (exposure), a circuit pattern of the mask is baked to expose to the wafer by the above-described exposing apparatus. At step 17 (development), the exposed wafer is developed. At step 18 (etching), a portion other than the developed resist image is scraped off. At step 19 (resist exfoliation), the unnecessary resist finished with etching is removed. By repeatedly carrying out the steps, the circuit

pattern is formed in multiple on the wafer.

[0127]

When the fabricating method of the embodiment is used, a semiconductor element of a highly integrated degree which has been difficult to be fabricated in the prior art can be fabricated.

[0128]

[Advantage of the invention]

According to the invention, by setting respective elements as described above, there can be achieved the exposure apparatus and the method of fabricating the device by using the method which are improved preferably for imaging the small pattern.

[0129]

Further, according to the invention, when the pattern having the periodicity is projected onto a predetermined face by the projection optical system, by pertinently setting the polarized state of the light beam used for projection in correspondence with the direction of the period of the pattern, there can be achieved the image projecting method and the exposure apparatus, and the fabricating method preferable for fabricating the semiconductor element capable of projecting the pattern by a high contrast while maintaining the high resolution.

[Brief Description of the Drawings]

[Fig. 1]

Fig. 1 is an outline view of an essential portion of embodiment 1 when an image projecting method of the invention is applied to a steeper.

[Fig. 2]

Fig. 2 is an explanatory view of an reticle of Fig. 1.

[Fig. 3]

Fig. 3 is an explanatory view showing a behavior of illuminating light to the reticle of Fig. 1.

[Fig. 4]

Fig. 4 is an explanatory view of an aperture of Fig. 1.

[Fig. 5]

Fig. 5 is an explanatory view of a polarization apparatus of Fig. 1.

[Fig. 6]

Fig. 6 is an explanatory view of other embodiment of the reticle of Fig. 1.

[Fig. 7]

Fig. 7 is an explanatory view of a portion of Fig. 6.

[Fig. 8]

Fig. 8 is an explanatory view of a portion of Fig. 6.

[Fig. 9]

Fig. 9 is an explanatory view of a reticle according to embodiment 2 of the invention.

[Fig. 10]

Fig. 10 is an explanatory view of an aperture according to embodiment 2 of the invention.

[Fig. 11]

Fig. 11 is a view showing a pattern on a reticle.

[Fig. 12]

Fig. 12 is a view showing a section of the pattern on the reticle of Fig. 11.

[Fig. 13]

Fig. 13 is a view showing an aperture according to embodiment 3 of the invention.

[Fig. 14]

Fig. 14 is a view showing a polarization apparatus according to embodiment 3 of the invention.

[Fig. 15]

Fig. 15 is a view showing a relationship between the pattern of Fig. 11 and polarization of illuminating light.

[Fig. 16]

Fig. 16 is a view showing a relationship between the pattern of Fig. 11 and polarization of illuminating light.

[Fig. 17]

Fig. 17 is a view showing a pattern on a reticle according to embodiment 3 of the invention.

[Fig. 18]

Fig. 18 is a view showing an operation of polarization converting apparatus according to embodiment 3 of the

invention.

[Fig. 19]

Fig. 19 is a view showing a relationship between the pattern of Fig. 17 and polarization of illuminating light.

[Fig. 20]

Fig. 20 is an outline of an essential portion of embodiment 4 when an image projecting method of the invention is applied to a stepper.

[Fig. 21]

Fig. 21 is an explanatory view of a portion of Fig. 11.

[Fig. 22]

Fig. 22 is an explanatory view of a portion of Fig. 11.

[Fig. 23]

Fig. 23 is an explanatory view of a reticle according to embodiment 5 of the invention.

[Fig. 24]

Fig. 24 is a flowchart diagram of a method of fabricating a semiconductor element according to the invention.

[Fig. 25]

Fig. 25 is a flowchart diagram of a wafer process according to a method of fabricating a semiconductor element according to the invention.

[Fig. 26]

Fig. 26 is an explanatory view showing an amplitude distribution on a pupil.

[Fig. 27]

Fig. 27 is an explanatory view for explaining a difference in a polarizing direction by an angle of a light ray.

[Fig. 28]

Fig. 28 is an explanatory view showing an intensity distribution on an image face when light polarized in a direction in parallel with a slit is used.

[Fig. 29]

Fig. 29 is an explanatory view showing an intensity distribution on an image face when light polarized in a direction orthogonal to a slit is used.

[Fig. 30]

Fig. 30 is an explanatory view of an intensity distribution on an image face by a phase shift method, an oblique incidence illumination when light polarized in a direction in parallel with a slit is used.

[Fig. 31]

Fig. 31 is an explanatory view of an intensity distribution on an image face by a phase shift method, an oblique incidence illumination when light polarized in a direction orthogonal to a slit is used.

[Fig. 32]

Fig. 32 is an explanatory view showing an amplitude transmittance of a repeated pattern.

[Fig. 33]

Fig. 33 is an explanatory view showing an amplitude distribution on a pupil.

[Fig. 34]

Fig. 34 is an explanatory view showing an intensity distribution on an image face.

[Fig. 35]

Fig. 35 is an explanatory view showing an amplitude distribution on a pupil when the phase shift method is used.

[Fig. 36]

Fig. 36 is an explanatory view showing an amplitude distribution on a pupil when an oblique incidence illumination is used.

[Description of Reference Numerals and Signs]

1 light source

2 optical integrator

3 illumination lens

4 reticle

5 projection lens

6 semiconductor wafer

7 stage

8 aperture

9 polarization apparatus

[Drawings]

[Fig. 24]

semiconductor device fabricating flow

(step 1) circuit design

(step 2) mask fabrication

(step 3) wafer fabrication

(step 4) wafer process (prestep)

(step 5) integration (poststep)

(step 6) inspection

(step 7) delivery

[Fig. 25]

wafer process

(step 11) oxidation

(step 12) CVD

(step 13) electrode formation

(step 14) ion implantation

(step 15) resist process

(step 16) exposure

(step 17) development

(step 18) etching

(step 19) resist exfoliation

repeat